THE COMPARISON OF TOPOGRAPHIC PAPER SURFACE CHARACTERISTICS BASED ON ROUGHNESS AND SMOOTHNESS

USPOREDBA TOPOGRAFSKIH KARAKTERISTIKA POVRŠINE PAPIRA TEMELJEM HRAPAVOSTI I GLATKOSTI

Katja Petric Maretić[1], Maja Rudolf[1], Irena Bates[1], Ivana Plazonić[1]
[1]University of Zagreb, Faculty of Graphic Arts, Getaldićeva 2, Zagreb, Croatia

Abstract

Topographic paper surface characteristics significantly affect general print quality. Several methods for measuring and numerical characterization of paper surface characteristics have been developed. Three elementary approaches to measurement of paper surface smoothness or roughness are in use: optical methods, profilometric methods and pneumatic methods. Although these three types of methods serve the same purpose, they differ from each other in the manner how the paper properties are presented. This study is based on two pneumatic methods, Bendtsen for measuring roughness and Bekk for measuring smoothness of the paper surface. The comparison of these two paper surface characteristics has been made on three types of offset paper (coated, uncoated and recycled paper).

Keywords: roughness, smoothness, pneumatic method, paper surface

Sažetak

Topografske karakteristike površine papira bitno utječu na ukupnu kvalitetu otiska. Razvijeno je više metoda za mjerenje i numeričko karakteriziranje svojstava površine papira. Tri su osnovana pristupa mjerenjima glatkosti ili hrapavosti površine papira – optičke metode, profilometrijske metode i pneumatske metode. Premda te tri vrste metoda služe istoj svrsi, međusobno se razlikuju u načinu prikaza svojstava površine papira. Ovo istraživanje bazira se na dvije pneumatske metode, Bendtsen za mjerenje hrapavosti i Bekk za mjerenje glatkosti površine papira. Na temelju toga uspoređuju se dva spomenuta svojstva koja su mjerena na tri vrste ofsetnog papira (premazani, nepremazani i reciklirani papir).

Ključne riječi: hrapavost, glatkost, pneumatska metoda, površina papira

1 Introduction

1. Uvod

When considering paper surface characteristics, it is crucial to achieve good print quality. One of the most important measurable characteristics of the paper surface that has a significant impact on the print quality is its smoothness or roughness. The greater the smoothness of the paper surface, the better the paper printability [1].

Smoothness and roughness of the paper surface are two semantic complementary concepts. The first of them, smoothness, signifying a deficiency or a lack of irregularities that disturb the ideal surface of the plane, while the other, roughness, signifies just the deviations in the topography of the ideal plane. These properties depend on numerous parameters relating to the composition of paper as well as to all phases of paper production process [2, 3].

Measuring these paper characteristics is not trivial. The true 3-D topography of the paper surface can be obtained by profilometers that use mechanical or optical sensors to measure three-dimensional surface deviations from the ideal plane. Various optical methods study paper surface roughness based on the light interaction with paper surface by measuring, for example, light scattering. Today, measurement methods in the paper industry are largely oriented to the pneumatic approach, i.e. to the measurement of different parameters in the leakage of defined air volume between two parallel surfaces - the paper

surface itself and some smooth, solid, mostly glass or metal surface - which are clamped under certain pressure. Generally, the larger the air flow, the higher the roughness of the paper surface. Three basic pneumatic methods are distinguished considering the measurement of different parameters, i.e. with respect to expressing roughness or smoothness in different units. The Parker Print-Surf (PPS) method measures airflow resistance and then converts to the mean roughness of the paper surface expressed in micrometers (μm) [4]. The Bendtsen method measures the air flow rate and the roughness is expressed in milliliters of air per minute (ml / min) [3]. The Bekk method measures the flow time of a precisely defined volume of air and the smoothness of the paper surface is expressed in seconds (s) [2]. This study compares the roughness of the paper surface, measured by the Bendtsen method, and the smoothness of the paper surface, measured by the Bekk method, on seven different types of paper.

2 Experimental part
2. Eksperimentalni dio

The air-leak methods for measuring roughness or smoothness of paper surface are indirect methods and generally, experience shows there is no exact correlation among the results obtained by using various methods for determining these characteristics [5]. Pneumatic devices used for measuring roughness or smoothness of paper surface are designed to give numerical values of roughness or smoothness expressed in different units [6]. Their designs differ significantly among them although they are all based on the same principle of the air-leak method, i.e. on an air leakage between paper or board surface and a reference metal or glass plane pressed together under a defined pressure [7].

Paper surface smoothness is often described in terms of paper surface roughness where a lower result indicates a smoother paper surface. Smoothness is usually measured with the Bekk method, and roughness with the Bendtsen method (Table 1).

Table 1 International standards for roughness and smoothness

	Bendtsen [ml/min]	Bekk [s/10 ml]
Paper surface ROUGHNESS	ISO 8791-2	
Paper surface SMOOTHNESS		ISO 5627

2.1 Roughness – Bendtsen measuring method

Bendtsen roughness is a measure of the rate at which air passes between a flat circular metal head representing the reference plane and a test paper or cardboard placed on a flat plate at a nominal pressure of 1.47 ± 0.02 kPa. The measuring head is made of corrosion resistant metal with internal diameter of 31.5 mm ± 0.2 mm, it is 0.150 mm ± 0.002 mm wide and with a mass of 267 g ± 2 g. Air is supplied to the space enclosed inside the head and then the rate of air flow between the head and paper surface is measured. These values are expressed in milliliters of air per minute (ml/min).

Measurement range of paper or board roughness values determined using this method is in the interval from 5 ml/min to 3000 ml/min [3]. Measuring principle is presented in Figure 1, where A is Pressure regulator; B Flow meter; C Pressure meter for actual pressure in the measuring head; D Paper; E Glass plate; F Measuring head, respectively [8].

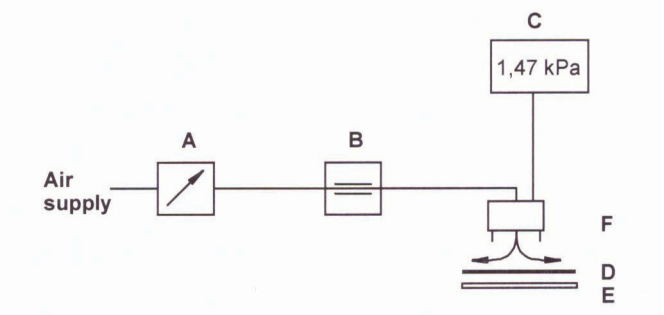


Figure 1 Measuring principle of the Bendtsen tester

2.2 Smoothness – Bekk measuring method

Bekk smoothness is measured by the air leak method but, unlike the Bendtsen method, air is drawn across the surface of the test piece under a partial vacuum.

Bekk method allows measuring time which is required to draw 10 ml of the ambient air into large vacuum container or 1 ml of the air into small vacuum container at atmospheric pressure between the sample of paper or board and the glass plate where paper is placed, after a vacuum corresponding to 50.7 kPa is created. So Bekk smoothness is time in seconds that expresses time interval needed to drop the vacuum from 50.7 kPa to 48.0 kPa. Results in seconds obtained when measuring with the smaller container has to be multiplied by 10. If measuring time is less than 15 seconds, the vacuum drop interval from 50.7 kPa to 29.3 kPa has to be used and then 80 ml of the air enters the large container or 8 ml of the air the small container [2].

This method of measuring the smoothness range of 4 to 1400 s is suitable for wide span of paper and board types but it is not recommended for material with the thickness greater than 0.5 mm or very permeable papers and boards. The higher the paper permeability, the bigger the amount of air passing through it, that can influences the result.

The principle of measurement is shown schematically in Figure 2. As air at atmospheric pressure has to be drawn between the test paper surface and a circular plane surface on the glass plate, the smoothness of contact paper surface is measured.

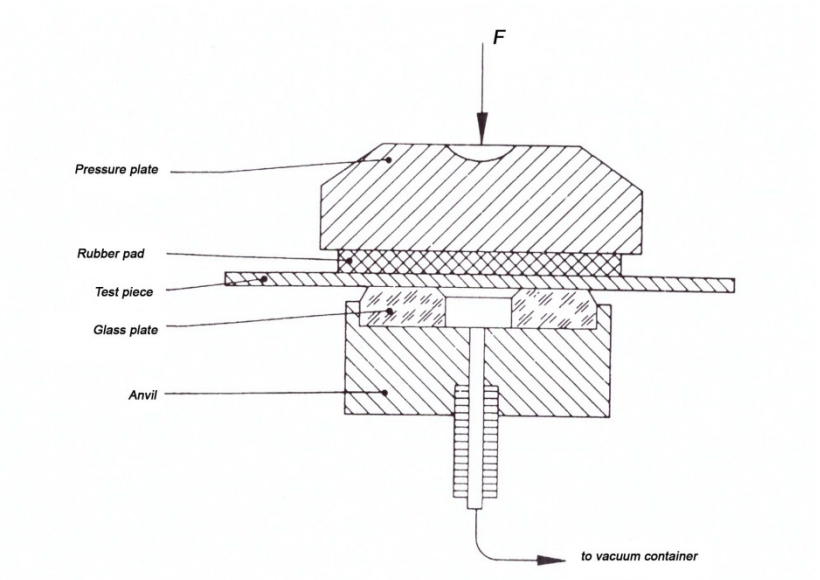


Figure 2 Measuring principle of the Bekk tester

2.3 Comparison of two methods

Despite of using air-leak method as a principle of measuring paper surface smoothness or roughness two pneumatic devices differ in their construction, what is presented in Figure 3.

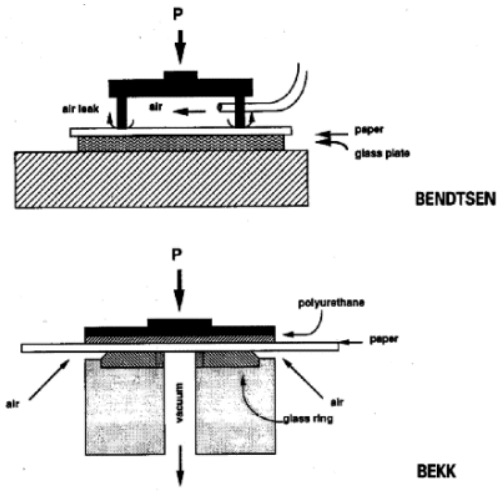


Figure 3 Different pneumatic devices [7]

Bendtsen roughness results are instantaneous whereas Bekk smoothness measurements take some time to achieve vacuum and a longer measuring time respectively. Technical characteristics of Frank Bendtsen roughness tester and PTI line Bekk tester are presented in Table 2.

Table 2 The differences between Bendtsen method and Bekk method

	Bendtsen method	Bekk method
Clamping pressure (kPa)	1.47 ± 0.02	50.70 – 48.00 (negative pressure)
Measuring head	Enclosed metal head with the flat lower surface with internal diameter 31.5 mm ± 0.2 mm and mass 267 g ± 2 g	Anvil with circular, plain, glass surface with the small hole (diameter = 1-2 mm, effective area 10 cm2 ± 0.05 cm2)
Flat plate / Pressure disk	Flat glass plate	Pressure disk (force of 100 ± 5N)
Suction (ml)	/	10
Unit of expressed result	Measure of the rate at which air will pass out (ml/min)	Time when air flows out (s)
Measurement range	5 ml/min – 3000 ml/min	4s – 1400 s

3 Methodology and results

3. Metodologija i rezultati

Analyzed paper characteristics were determined according to ISO standards (Table 1). Roughness was measured according to Bendtsen method with Frank Bendtsen roughness tester and smoothness

according to Bekk method with PTI line Bekk tester. Analyses were conducted on seven types of commercial papers, all of them produced by United Paper Mills from Finland (UPM). They differ among them by coating and weight (Table 3).

Table 3 Weights and labels of printing substrates produced by United Paper Mills

Printing substrates	Weight	Label
Newsprint	42.5 g/m2	NP
Uncoated offset paper	70 g/m2	UOP 70
Uncoated offset paper	80 g/m2	UOP 80
Uncoated offset paper	100 g/m2	UOP 100
Matt coated offset paper	70 g/m2	COP 70
Matt coated offset paper	80 g/m2	COP 80
Matt coated offset paper	100 g/m2	COP 100

The topographic information of all the paper samples was taken by Dino-Lite digital microscope Pro (magnification 200x) [9]. 3D surface plots diagrams were created in ImageJ image analyzer.

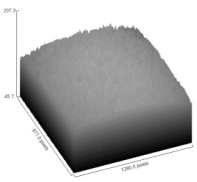
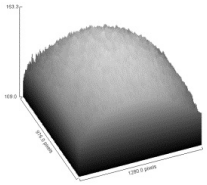
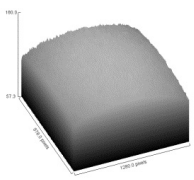
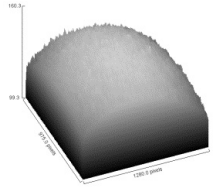
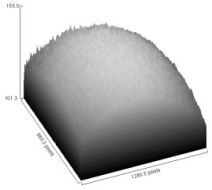
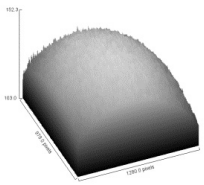
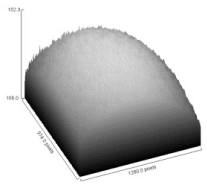
Offset paper	NP	70 g/m2	80 g/m2	100 g/m2
Uncoated				
Coated				

Figure 4 3D surface plots diagrams of all paper sample felt sides

Differences based on paper surface roughness and smoothness of uncoated and coated papers cannot be detected on 3D surface plots diagrams.

Values obtained by Bendtsen and Bekk methods are presented as arithmetic means of 20 measurements on each sheet paper side (both felt and wire sides) in roughness – smoothness diagram (Figure 5 and 6).

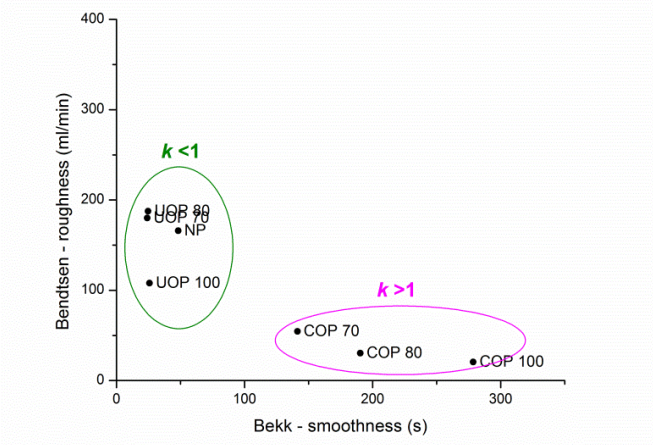


Figure 5 Roughness and smoothness mean values of felt paper side

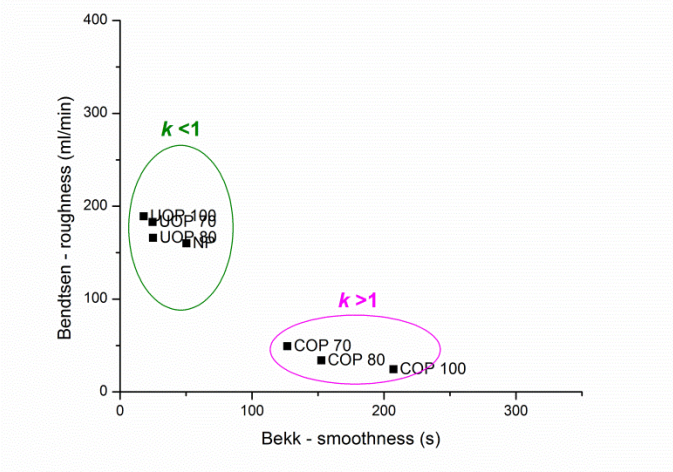


Figure 6 Roughness and smoothness mean values of wire paper side

The relationship of paper surface characteristics was observed and expressed by value k that means smoothness over roughness ratio:

k=S/R=Smoothness/Roughness (1)

Table 4 Values k for felt and wire sides of different papers

Printing substrates	kfelt	kwire
NP	0.34	0.29
UOP 70	0.13	0.13
UOP 80	0.15	0.13
UOP 100	0.09	0.24
COP 70	2.57	2.59
COP 80	4.49	6.29
COP 100	8.46	13.59

Obtained results show there is no significant difference between felt and wire paper sides, regarding to their smoothness or roughness. As roughness value increases, smoothness value decreases and vice versa, although the mathematical relation has not been found.

The value of k can be < 1 or > 1, determining if paper surface is rougher or smoother. In that way uncoated and coated papers form separate groups, where uncoated papers (having k < 1) are generally rough, while coated papers (having k > 1) are in general smooth.

4 Conclusions
4. Zaključak

On the basis of the data obtained by this research the following conclusions are made:

- there is no considerable difference in paper surface smoothness and roughness between felt and wire paper sides

- considering the results of measurements of different papers, separate groups are formed by uncoated and coated papers

- comparing smoothness and roughness characteristics with these values in ratio k it could be concluded that k <1 refers to uncoated papers and k >1 refers to coated papers

Literature
Literatura

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Corresponding person:

Asst. prof. Irena Bates

E-mail: irena.bates@grf.hr

Getaldićeva 2, 10 000 Zagreb